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NOTES ON THE JAMAICA EARTHQUAKE

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INTRODUCTION

The following notes on the Jamaica earthquake are based upon observations made by the writer during a visit to Kingston in March, 1907, and upon interviews with government officials and others who were present in the city at the time of the disaster. Special thanks are due to Mr. Robert Simmons, A. I. C., of the Government Laboratories for information furnished, and to Mr. F. G. Clapp of the United States Geological Survey, who was associated with the writer in his studies and who has supplied several of the photographs accompanying the present paper. Owing to the shortness of the stay at Kingston the observations were of necessity somewhat limited, and no claim for completeness can be made, the object of the paper being simply to present some of the more important results of the earthquake as observed by the writer or described to him by eye-witnesses.

The city of Kingston is located on the south side of Jamaica, on the seaward edge of a large alluvial fan, occupying a V-shaped re-entrant in the mountains. In front of it is a spacious harbor, separated from the open sea by a long sand-spit, stretching westward for a distance of eight miles from the mainland, at a point about four miles southeast of the city. The relations are shown in Fig. 1.

GEOLOGY

The island of Jamaica consists essentially of an east-west core of metamorphosed Cretaceous shales, conglomerates, serpentine limestones, etc., standing at high angles and cut by granitic intrusions, surrounded by a narrow belt of younger and less disturbed Cretaceous sands, marls, and limestones, around which in turn is a wide belt of Eocene limestones, etc., with a few patches of Neocene around the edges. The structure is anticlinal, the trend of the uplift being from a little north of west to south of east. A considerable number of faults occur with trends parallel to the structural ridge while others are approximately at right angles to it. Large alluvial fans are found in indentations of the mountains at many points.

TOPOGRAPHY

In a general way the topography depends on the geologic structure, the mountainous areas corresponding with the upturned metamorphic tracts and the broad plateaus bordering the mountains, especially to the west, coinciding with the younger and less disturbed Eocene beds.

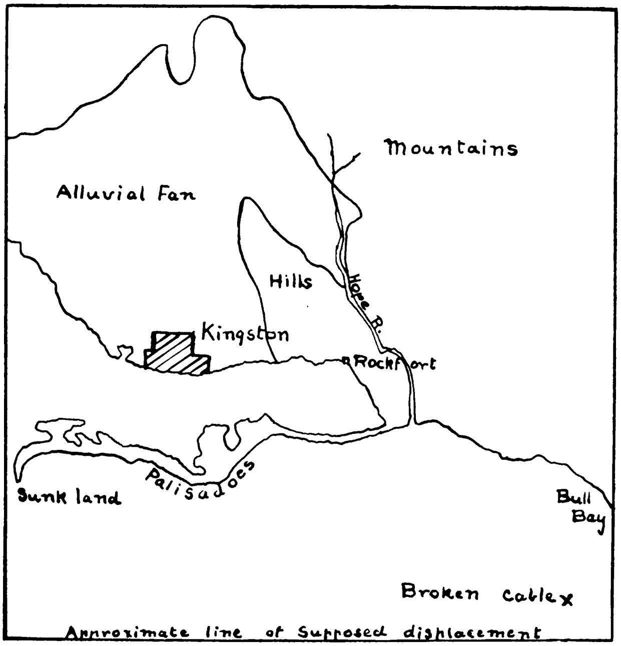

FIG. 1.—Sketch map illustrating location and surroundings of Kingston, Jamaica.

GENERAL SEISMIC CONDITIONS

Seismic disturbances have been of frequent occurrence in the island of Jamaica since its settlement, but in general the shocks have been of slight intensity. In 1692, however, an earthquake of great severity took place, engulfing such parts of the city of Port Royal as were built upon the sand-spit across the harbor opposite the present site of Kingston, and seriously damaging smaller areas built on the limestone reef. In the 200 years following this great shock the island was shaken from time to time by minor disturbances, some of which were of some intensity, but no record seems to have been kept until the latter part of the last century. The records available to the writer[1] covered the period from February 19, 1880, to November 25, 1906, during which 163 shocks were felt. Their distribution, which is shown in the accompanying table, indicates a maximum in the autumn and winter months with a minimum in the spring and summer months. The activity shown in the last column is computed by assuming that two shocks of Intensity I are equal to one of Intensity II, and that two of Intensity II equal one of Intensity III. In other words, I equals one, II equals two, III equals four, IV equals eight, etc.

From the table it will be noted that the activity is 198 in the night hours (6 P. M. to 6 A. M.) as compared with 150 in the day (6 A. M. to 6 P. M.). The principal activity is from 2 to 5 o'clock in the morning with a lull at daybreak followed by a marked increase in the activity from 7 until 9. From 9 until 1 there are very few shocks, but from 2 to 4 the number is again high, after which it drops to a very low point from 5 to 7 o'clock. In the evening there is a strong rise between 8 and 10 o'clock, after which there is a falling off until the 2 to 4 o'clock period the following morning. This early morning period of activity (2 to 4 A. M.) corresponds with one of the minima of the diurnal variations of barometric pressure. The forenoon period of low activity, from 9 to 11, corresponds with the forenoon maximum; the afternoon period of intensity, from 2 to 4, with the corresponding barometric minimum. Up to this point the disturbances agree with that postulated by the advocates of greatest activity during barometric minima with least activity during the maxima. The evening period of barometric maximum, which according to theory should be a period of minimum activity, however, is in reality one of great activity, while the least activities of all are found at daybreak and sunset when theoretically they should be of intermediate activity. These variations are not confined to the Jamaica earthquake, but have characterized others, especially the New Madrid earthquake of the Mississippi Valley in 1811, the record of the shocks of which were carefully kept during the period of disturbance, which lasted over a year. The table of these shocks shows nearly the same features throughout as the tabulated data above. Just what the factors are which give rise to the peculiarities of distribution are not known, but they appear to be of a general rather than a local nature.

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[1] Maxwell Hall, published in the local press, February 18, 1907

SEASONAL DISTRIBUTION OF JAMAICA EARTHQUAKES, 1880–1906

	I	II	III	Activity
Spring (March, April, May)	21	10	1	45
Summer (June, July, August)	16	11	1	42
Autumn (September, October, November)	41	11	2	71
Winter (December, January, February)	35	9	5	73

DIURNAL DISTRIBUTION OF EARTHQUAKES

Based on 163 shocks previous to November 25, 1906, and 90 shocks after that date

Hour	I	II	III	Activity
12 M.	7	2	1	15
1 A. M.	3	3	1	13
2 A. M.	11	5	2	29
3 A. M.	13	9	..	21
4 A. M.	8	2	..	12
5 A. M.	9	5	..	19
6 A. M.	7	1	..	9
7 A. M.	12	3	1	22
8 A. M.	10	1	..	12
9 A. M.	5	3	..	11
10 A. M.	6	..	..	6
11 A. M.	7	..	..	7
12 M.	9	2	..	14
1 P. M.	6	2	..	10
2 P. M.	9	3	1	19
3 P. M.	4	4	2	20
4 P. M.	7	2	..	11
5 P. M.	5	2	..	9
6 P. M.	5	1	..	7
7 P. M.	6	1	..	8
8 P. M.	4	4	1	16
9 P. M.	11	1	1	17
10 P. M.	12	4	1	24
11 P. M.	9	1	1	15

Of the disturbances preceding the principal shock, that occurring in November, 1906, was the most severe, rattling dishes, shaking a few bottles, etc., from shelves, and producing slight cracks in a few instances, being a stronger shock than any subsequent to the main disturbance.

THE RECENT EARTHQUAKE

WEATHER CONDITIONS

At the time of the recent severe shock, which occurred a little after half-past three in the afternoon, the barometer stood at 29.551, which is normal for the locality and elevation. The weather was clear. The shock occurred near the date of the new moon at which period, it is claimed by some, the Jamaica earthquakes are particularly likely to occur, owing to the supplementary attraction due to the conjunction of sun and moon. A comparison with the table above also shows that it took place near the afternoon period of maximum intensity.

TIME AND DURATION

The principal shock, which was the only one producing any serious damage, took place at 33 minutes and 6 seconds past 3 o'clock in the afternoon of January 14, 1907, and lasted about 30 seconds. The vibrations were not of uniform strength, but were marked, according to descriptions, by at least three recurrent pulsations of alternating low and high intensities.

CHARACTER OF MOVEMENT

Direction of vibrations.—Those who experienced the shock in Kingston are generally of the opinion that the vibrations were along an east-west line, but whether from the east or from the west there is some disagreement. That the principal movement was along the line indicated is further attested by the fact that the east and west ends of buildings were most commonly thrown down, east and west walls more frequently buckled and crushed, and cracks in the walls mainly in east and west directions. As will be seen later the epicenter was very near Kingston, and there was more or less deflection of the waves by the surrounding mountains, doubtless giving rise to complications of movement which more or less disguised the normal direction of transmission.

Nature of vibrations.—The nature of the earth movements depended largely upon the character of the underlying material at the point where the shock was observed. On the solid rocks and on the compact semi-cemented alluvium on which Kingston is situated the movements were of the short, sharp, tectonic type, there being practically nothing in the nature of the undulatory surface wave. At Port Royal, on the other hand, the surface waves predominated, the ground rising and falling as the movement progressed in the same manner as do the waves upon the sea.

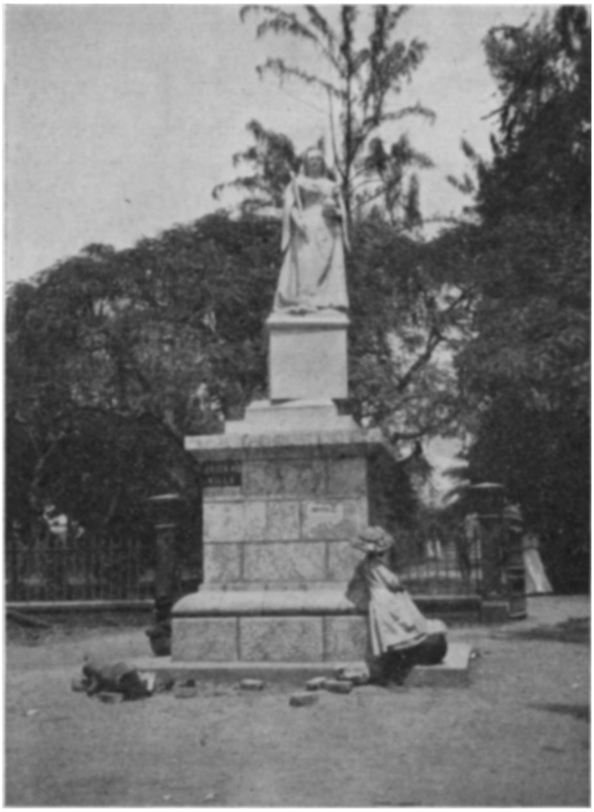

FIG. 2.—Southward facing statue of Queen Victoria, twisted in anti-clockwise direction by tortional movements. (Photo by Fuller.)

The seismographs were put out of commission at the beginning of the shock, and for the nature of the shock personal observation must be depended upon. According to the accounts of those who were interviewed by the writer, the first vibrations seemed to come from below, the action somewhat resembling in effect the feeling one might experience if the floor on which one was standing were subjected to a hard blow from underneath. This was apparently followed by a rapid motion from side to side, and finally by a tortional motion which is described as shaking objects much as a terrier shakes a rat. It was this motion which produced the twisting exhibited by nearly all statues in the city (Fig. 2). As already indicated, there were three or more maxima of intensity during the shock. A feeling of intense confusion was experienced by those feeling the shocks but nausea was seldom produced.

Intensity and amplitude of the vibrations.—The amplitude of the vibrations appears to have been small. Only in occasional instances were street cars shaken from the tracks, few of the statues were overturned, and only a small number of telegraph, telephone, or trolley poles were overthrown or tilted. This would hardly have been the case if the lateral movement had been considerable. As nearly as can be judged from descriptions the movement was not over an inch.

The intensity of the shock, as attested by the ruins, however, was very high, the destructions being to a considerable extent due to a sort of disintegration, apparently resulting from very strong and rapid vibrations, which, however, were of short amplitude, at least in the rock areas and the stiff semi-compacted alluvium of the Kingston region.

ASSOCIATED PHENOMENA

Noise.—The earthquake was accompanied by a loud noise, described as a deep crushing sound, somewhat suggesting distant thunder but with less boom and more of a roar. Intermixed with the natural sounds proceeding from the earth was the crashing of the buildings and the cries of the people, the two together being described as almost deafening.

Dust.—One of the phenomena described by all eye-witnesses was the notable darkness following the shock. The local mortar, rather poor at the best, which was used in most of the buildings, pulverized quickly, and was projected into the air together with other dust in immense quantities as the buildings fell, saturating the atmosphere until it was almost impenetrable to the suns rays. After the cessation of the shock it slowly settled, covering everything with a thick white mantle of fine calcareous silt.

EFFECT ON INHABITANTS, ETC.

Behavior during earthquake.—The greater part of the inhabitants of the island of Jamaica are negroes or mulattoes, although a very considerable number of whites reside in the cities, especially in Kingston and Port Royal. The negroes, although Christianized, retain many of their superstitions and are very demonstrative, a fact which had an important bearing on their behavior and attitude during and subsequent to the earthquake. The very first shock threw them into the greatest fright, but it was far from a paralyzing fright either as regards speech or motion, for the majority fled precipitately from their houses into the streets and open places as a howling mob, alternately screaming and praying, sometimes, it is said, both at once. Even after the vibrations had ceased the excitement and noise continued for some time, and the greatest confusion prevailed. The police and troops were soon out, however. and the wrecked district

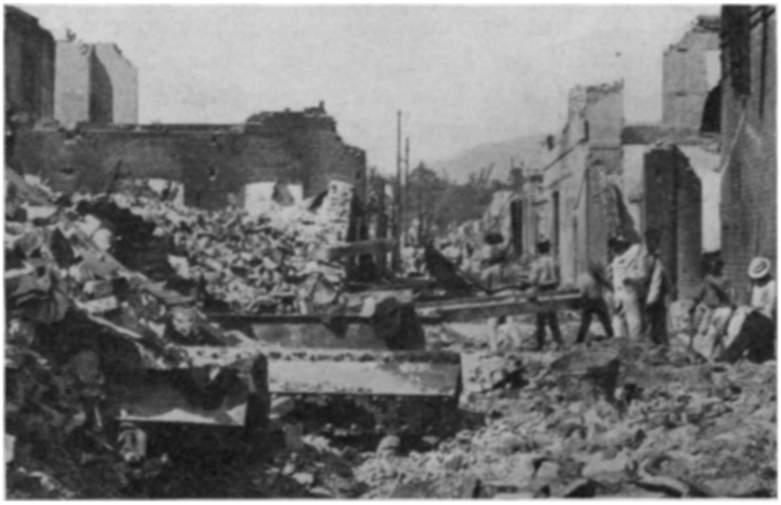

FIG. 3.—Wreckage in area of severe disturbance. In places the ruin was so complete that streets could be traced only with difficulty. (Photo by Cleary's Studio, Kingston.)

was carefully patrolled, no one without a pass being permitted to enter. Throughout the shock the whites behaved with a considerable degree of calmness, being without the unreasoning fear which characterized the blacks, yet none could reach the open too soon. Animals, wherever not thrown down by the shock, generally stampeded, horses, mules, and cattle being alike in this respect.

Loss of life.—The loss of life on the island, as compiled from identified remains and the list of missing, is officially given as 1,003, almost the whole number of casualties being at Kingston or vicinity. The high death list resulted from the fact that the shock occurred late in the afternoon when the stores and sidewalks were full of people. The loss in some of the stores was very large, that in the "Beehive," "Army and Navy," "Waterloo House," and "Croswell's" being greatest. From 25 to 40 sometimes lost their lives in a single store. At the Jamaica Club 7 out of 9 were killed, while in other buildings, like the Colonial Bank, everyone escaped. Many lost their lives upon the sidewalks, crushed by the falling buildings. The loss was greatest in Port Royal Street, Water Lane, and vicinity, which was one of the most completely wrecked districts, the position of some of the streets being hardly distinguishable amidst the rubbish after the shock. Few people in this vicinity escaped uninjured. So great was the destruction and accumulation of débris that at the time of the writer's visit, two months after the shock, bodies were still being recovered from the ruins.

Outside the city and vicinity the loss of life was not great, although a few people among the mountains were killed by falling rock or landslides. Of the deaths many were instantaneous, but many persons were caught in the ruins and burned in the conflagration which followed the shock. Twenty or thirty died subsequently from blood poisoning resulting from improperly dressed or neglected wounds. No epidemic of sickness has yet appeared.

EFFECT OF EARTHQUAKE

The results of the earthquake varied considerably according to the nature of the material constituting the surface at a particular point. Rock areas, alluvial fan deposits, and sand-spits are the principal types involved.

ROCK AREAS

Land slides.—The rock areas near Kingston are confined principally to the mountains, the narrow border of coastal plains being of unconsolidated materials. In the rock areas the surface is composed of disintegrated rock, bowlders of disintegration, etc., forming a mantle or talus over the hillsides. The slopes in many instances are very steep, and as a result of the earthquake many bowlders and avalanches were precipitated down the mountain sides, leaving great bare scars on their faces. In many cases trails were obliterated and roads ruined by slipping or by coverings of débris and, as already mentioned,

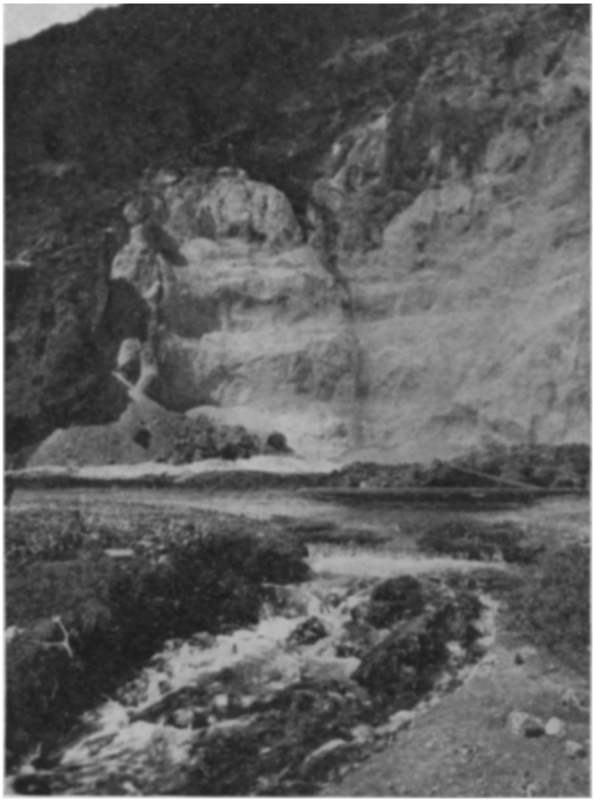

FIG. 4.—View of large spring (400 gallons per minute) resulting from rock fractures in soft limestone at Rockfort quarry. (Photo by Fuller.)

a few people were killed. In the large government quarry at Rockfort east of Kingston large pieces of the walls were broken down forming large heaps of débris.

Outbreak of springs.—Previous to the earthquake a single large spring had flowed from the limestone at the base of the quarry at Rockfort, but at the time of the shock a second spring, as large or larger than the original, broke forth through fractures produced at the time and flowed to the sea as a stream between three and four feet wide, five or six inches deep, and with a velocity of several feet per second. The water is salty and slightly thermal, and at times is said to be somewhat sulphurous.

ALLUVIAL DEPOSITS

Character.—The alluvial deposits, upon which Kingston was built, consist mainly of a gravel with a stiff, reddish, sandy clay matrix, binding the whole into a somewhat tough resistant mass. Geologically it belongs to a broad alluvial fan occupying a re-entrant in the mountains and rising from sea level at Kingston to an elevation of several hundred feet at the base of the mountains. Throughout the fan, except near its seaward edge, the ground water is rather deep and had but little effect on the phenomena of the earthquake, the material behaving, in fact, much like solid rock, being almost entirely without the warping, fissures, etc., such as usually characterize unconsolidated materials.

Earthquake fissures.—From the fact that the movements were of the nature of vibrations rather than visible earth waves it was not to be expected that fissures would be produced to any extent upon the mainland. In fact, it was only near the margins of stream gullies and along the sea margin—points where there was an opportunity for lateral displacement—that fissures were formed. Of the displacements along stream banks, those near the Hope Culvert were among the most pronounced, the aqueduct bearing a part of the city water being broken by the movement at this point. Along the water front the fissures were more numerous. Near Victoria Market, especially, a considerable number of small fissures parallel with the sea margin were formed, from which considerable amounts of sand and water were extruded. The latter, however, were from no great depth as the water level is here within a few feet of the surface. The locality on the mainland where the cracks are most numerous seems to be east of the city between the end of the trolley line and the government quarries at Rockfort. At this point the shock was not only more severe, but the road built on an artificial shelf at the water's edge and only five feet above it, offered especially favorable conditions for fissuring. Cracks were observed along this road for a distance of half a mile. Some were less than five feet in length and only about one inch in breadth, while others up to one hundred feet or more and with a width up to four inches were noted. Most of the cracks were irregu-

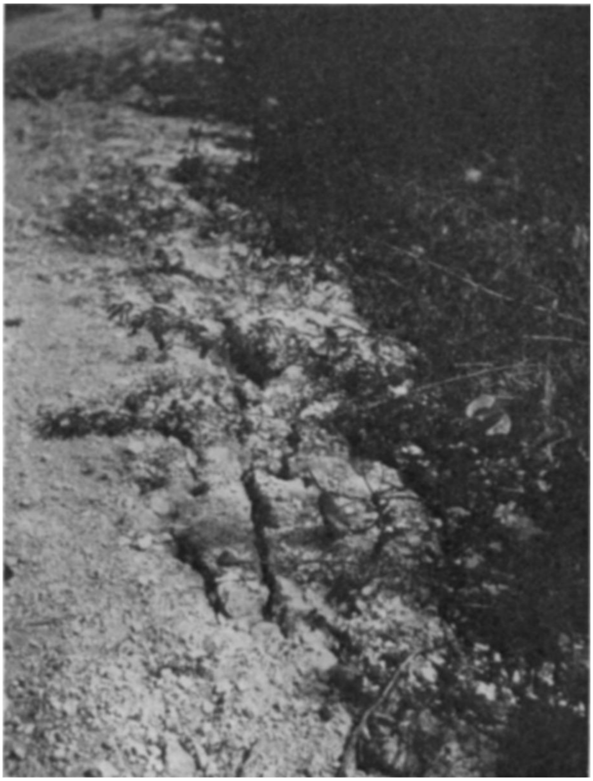

FIG. 5.—Earthquake cracks due to lateral displacement toward the sea, near Rockfort, Kingston. (Photo by Fuller.)

lar gaps, originally extending downward to the level of the sea from three to eight feet below. An interesting feature, however, was presented by the absolutely straight and regular fissures, sometimes fifty or more feet long, and determined by the line of excavation made years before for the sewer. In all cases the fissures were parallel to the water front and resulted from the separation of a narrow strip along its margin, generally slightly displaced and somewhat tilted toward the sea.

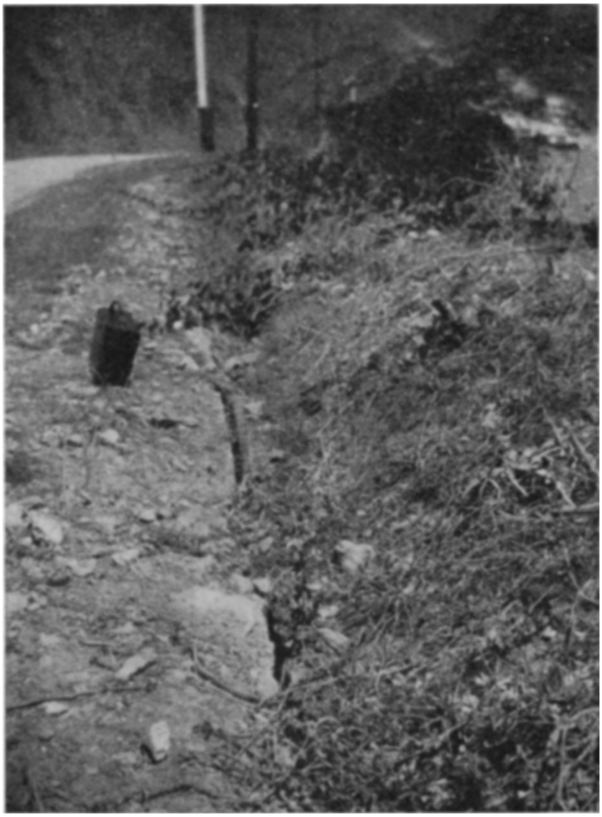

FIG 6 —Earthquake crack due to lateral displacement along line of old sewer excavation. (Photo by Fuller)

Faulting.—Very little faulting took place in the alluvial deposits, although slight displacements took place along some of the fissures. In one instance near Rockfort the road along the shore seemed to have fallen with reference to the sidewalk a distance of four to six inches, and at other points a sinking of the road of from one to two feet, doubtless owing to flowage of the underlying sand, seems to have occurred. In other cases the motion appeared to be the reverse, the segment containing the sewer sinking with reference to the road.

Extrusion of sand and water.—As already mentioned more or less sand and water was extruded from fissures near the water front at the Victoria Market, but, owing to the toughness of the alluvium, the depth of the water table, and the absence of large earth waves, the conditions were unfavorable for such action. No craterlets were reported, and there appears to have been no extrusion from the cracks along the Rockfort road as described above.

Change of level.—No noticeable change of level of the land, except in the fissured and slumped zones at the immediate margin of the sea has been recognized. So far as can be determined the water stands at the same level along the wharves as before the shock.

SAND SPIT (PALISADOES)

Extending from the mainland about four miles east of Kingston a long spit known as the Palisadoes stretches westward, a distance of eight miles, forming the harbor of Kingston. Patches of reef limestone representing original islands, reach the surface of the spit at at least two points. With the exception of these rocks the entire mass is composed of loose wave- and wind-drifted sands, standing only a few feet above sea level and saturated with water nearly to the surface. The conditions for the propagation of earth waves and for disintegration and slump were, therefore, far more favorable than in the tough alluvial deposits at Kingston, and, as would naturally be expected, the destruction was much more severe. On the limestone patches, on the other hand, the action was similar to that on the mainland.

Fissures and extrusions.—Fissures and extrusions of sand occurred at various places on the Palisadoes, especially near the point of connection with the mainland. Here long lines of closely spaced faults parallel to one another and to the sea margin were formed. The displacements of the individual faults was usually only from six inches to a foot, but the aggregate displacement amounted to many feet. Along some of the fault lines large quantities of sand and water were extruded, the points of emergence being now marked by long narrow craterlets. More or less fissuring and extrusions of sand are also said to have occurred at the end of the point at Port Royal, the cracks apparently opening as the crest of the earth wave advanced and closing (accompanied with the extrusion of sand and water to a height of several feet) as the crest gave way to the following trough. Most of this action was on the part of the point which finally sunk below the sea (Fig 7.).

Tilting and warping of surface.—Owing to the same incoherent nature of the materials there was not complete recovery from the earth waves, the surfaces at many points remaining in the form given them as the waves progressed. An even more important effect, however, appears to have been produced by the flowage of the saturated sands. The result of the two was to leave the surface bent and warped, a condition brought out strongly by the present attitudes of the artificial structures. Near the end of the point, as one enters the harbor, a wooden tower is observed tilted several degrees and the gun foundations equally out of level. On the inside of the point the sea wall is likewise tilted at a considerable angle, and one of the wharves is similarly inclined. Several of the flagpoles are much inclined and numbers of houses noticeably tilted, while in one case the middle of a building seems to have sunk several feet with reference to the ends, breaking it from bottom to top along the center. The railroad tracks at one point are reported arched up for a distance of twenty-five yards, the elevation of the center above the ends being estimated at about four feet, while lateral twists in the tracks were not uncommon. In some localities arches in the surface with angles from 3° to 10° are said to occur.

Subsidence and submergence.—The tilting and warping described in the last paragraph resulted from differential movement, parts of the surface being lifted while other parts sunk. In many instances the subsidence was sufficient to bring the bottom of the cellar below the level of the ground water so that water now stands above their floors. At one point on the north side of the Palisadoes the sinking was such that a lagoon formerly separated from the salt water by a beach twenty yards in width and two or three feet high was covered by the sea. Perhaps the most conspicuous change of level was at the extreme south-west point of the Palisadoes at the entrance of the harbor, where a body several hundred feet in length and breadth sunk beneath the waters of the ocean. Fig. 7, which represents a view of this point, shows the palm trees and shrubs, still upright, projecting from the water. The subsidence, which here seems to have been from ten to twenty feet, was probably due to a sort of flowage of the loose water-saturated sands underlying the surface at a depth of a few feet. A mangrove swamp on the harbor side of the Palisadoes is reported to have sunk ten feet.

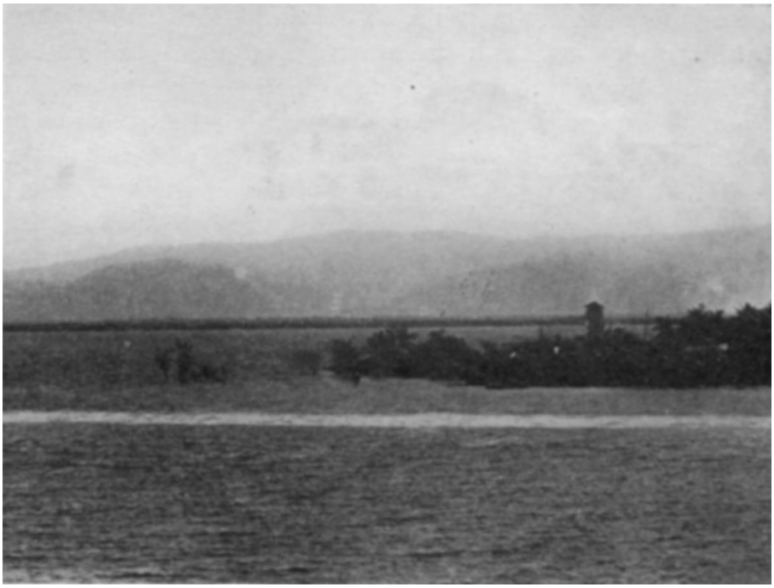

FIG. 7.—Submerged land at southwest termination of the Palisadoes at Port Royal. (Photo by Fuller.)

In addition to the cases mentioned, what may possibly be a case of subsidence was seen from the steamer off Morant Point at the east end of Jamaica, some forty miles from Kingston. The shore at this locality is low for some distance, only a narrow strip of beach showing between the water and the forest which here comes to the shore. In a few places this beach, as seen from a distance of not over a mile, seemed to be missing, the water reaching amongst the trees, the foliage of which appeared to be dried and withered as if recently killed by a subsidence which had admitted the sea.

EFFECT ON SEA BOTTOM

Kingston harbor.—Immediately following the earthquake many stories were circulated as to the obstruction of the harbor by mud flows, etc., but soundings in its channel showed that it had not been materially altered and vessels of deep draft soon entered and left as usual. Inasmuch as the bottom is prevailingly soft, and as the soft materials at Port Royal were much disturbed, there was doubtless much flowage wherever the bottom possessed any considerable inclination. The action was most marked, along the shores of Port Royal, where the bordering bottom sunk many feet in places, accompanied by a corresponding rise at a point farther out, or by at least an outward flowage of the soft deposits.

Sea bottom off coast.—On the sea bottom there appears, on the contrary, to have been disturbances of great magnitude, the center being, it is stated, some three or four miles off shore at a point southeast of the mouth of Hope River at the east end of the Palisadoes where they are attached to the mainland. In this locality the bottom is reported to have been decidedly roughened by movements of its soft materials, resulting in the breaking of the cable at points from three and one-half to fifteen miles off the coast. Several miles were so twisted, broken, or buried that new cable had to be laid. No such action occurred anywhere on or near the land, and, if accounts are to be relied upon, this is to be regarded as the region of greatest disturbance.

EFFECTS ON FORESTS

The action of the Jamaica earthquake on forests was relatively slight. On the mountains a few insecurely rooted trees were more or less tilted and some dead trees are reported to have fallen. The chief destruction, however, was by avalanches which not infrequently made paths many feet wide for several thousand feet down the mountain sides. On the Palisadoes and in similar situations where the surface caved or sunk beneath the sea, many trees were submerged and killed by the salt water. The possible submergence of considerable areas in this way at Morant Point was suggested on a previous page.

EFFECT ON ARTIFICIAL STRUCTURES

Kingston

The intensity of the Jamaica earthquake was very great and the destruction correspondingly severe, the ruin apparently being equal to, if not surpassing, that in the Charleston and San Francisco earthquakes in our own country. While some high buildings escaped complete demolition, nearly all were badly wrecked, while in many cases even the one-story houses and stores were destroyed. The destruction was not uniform, however, varying greatly according to the nature of the materials used in construction. In the order of their resistance the structures were of steel, wood, stone, concrete, and brick.

Brick structures.—In the brick structures some of the most interesting forms of destruction were exhibited by the posts forming parts of the fences found in front of a great number of houses. The usual method followed in the construction of the fence was the erection at intervals of from ten to fifteen feet of square brick posts, about one and one-half feet in diameter and five or six feet tall, between which iron or wooden picket fences were placed. When the vibrations struck the fences the brick posts were in 90 cases out of 100 broken off at their base, falling en masse at right angles to the fence, especially where it ran in a north-south direction. In several instances the brick posts were thrown out of the fence, leaving the wooden palings standing. On the east-west streets the posts were sometimes thrown toward each other, crushing the wooden or buckling the iron fences between. Besides the destruction of the posts en masse some were disintegrated by the shock, the bricks of the center being loosened and causing a marked bulging. A few more vibrations and the whole would have crumbled.

The destruction of the brick garden walls was also severe, everything over 3 feet in elevation being generally badly injured. On north-south streets there was a tendency to fall en masse, while in east-west streets, tortional warping, disintegration, and the breaking away of large chunks was common.

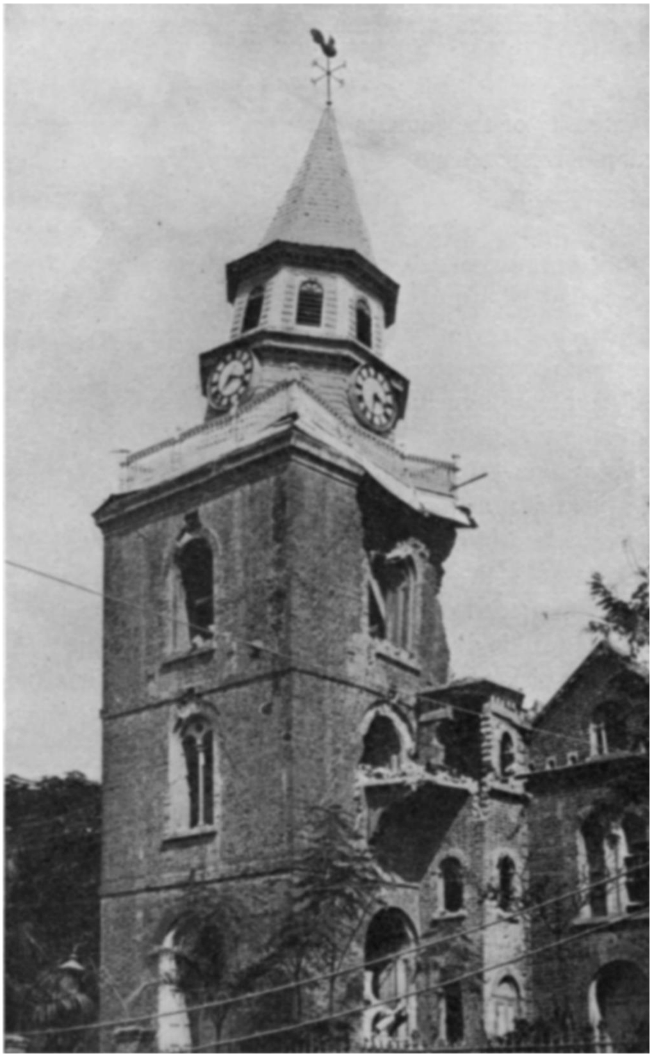

FIG. 8.—Wrecked church tower. Note clock stopped at 3:35. The tower has since fallen. (Photo by Cleary's Studio, Kingston.)

The action on brick buildings was variable. The better class stood in some cases through both shock and fire, although the motion was sufficient to snap flagpoles at their tops. The churches fared very badly, most of them, even where not completely demolished, being practically ruined, the damage being such that they had to be pulled down (Fig. 8). The fact that they had little interior strengthening in the way of partitions probably contributed to this result. The cracks generally meandered irregularly, but approximately diagonally through the brick walls, commonly making an angle of about 45° with the horizon. In other cases the action seemed to be largely one of disintegration, the latter being assisted by the rather poor local mortar commonly used. In general the destruction on the north-south streets seemed more complete than in the east-west streets.

Stone structures.—There were relatively few stone structures in the city or vicinity. Of these the Government Laboratories, several miles away, were almost unaffected, only a few small cracks, not necessitating repair, being developed. At the Colonial Bank, composed of stone and brick, the destruction was greater, but none of the occupants was killed, while many in surrounding brick buildings lost their lives.

Cement structures.—Only one cement structure was seen by the writer. This was the building of the Jamaica College, situated near the Government Laboratories just mentioned. Unlike the latter, however, it was so badly wrecked that a portion had to be pulled down and the whole practically rebuilt. The action was one of cracking rather than of disintegration. The cement was not reinforced to any extent.

Wooden structures.—The frame houses were considerably wrenched and twisted by the shock, and their plastering was often cracked or shaken down, but, owing to their elasticity, they generally escaped demolition, and after cleaning and a few repairs were ready for reoccupancy. A few wooden buildings were wrecked, however, in the eastern part of the city where the action was especially severe.

Steel structures.—There were no steel office buildings in the city, but two markets, the Victoria on the water front (Fig. 9) and a similar one near the public square were built mainly of this material. They were little affected by the shock, presenting almost no outward signs of disturbance, although the former was near the water's edge where the ground was much agitated and small fissures opened. They were still usable after the shock.

Combination buildings.—The type of dwelling having a lower story of brick and an upper story of wood was very common at Kingston, but was, unfortunately, not adapted to resist the earthquake disturbances. The brick portion was invariably damaged and in a great many cases collapsed completely, the wooden upper part often resting on the ground, its integrity essentially preserved, presenting a striking lesson in the relative resistances of the two materials.

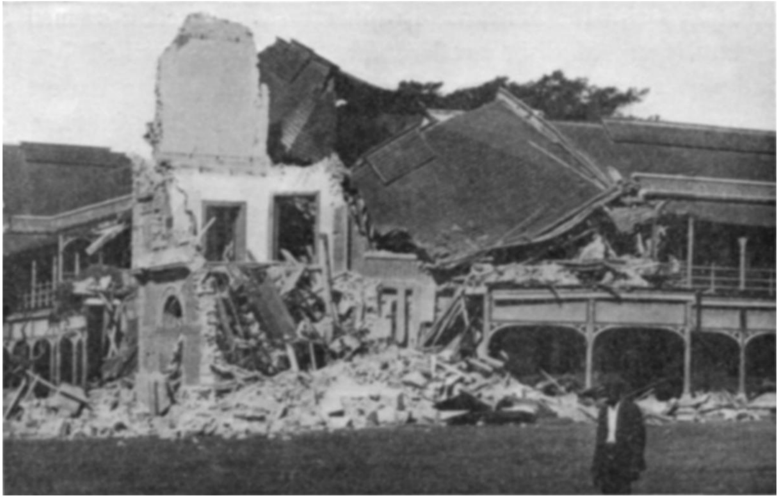

FIG. 9.—Showing complete demolition of brick tower while wooden porches are unaffected. (Photo by Cleary's Studio, Kingston.)

Windows.—One of the striking features of the earthquake was the few windows which were broken. In many instances the window frames, without a single pane broken, were seen where the brick walls surrounding them had crumbled and fallen. This immunity seems to indicate that while there was much shaking there was relatively little tortional or crushing movements in the walls. The peculiar feature of window panes perforated by clean-cut round holes, but not otherwise shattered, were also a striking feature, apparently resulting from bricks or other objects thrown laterally with considerable velocity by the shock.

Curbings and pavings.—In general there was no disturbance of the curbings or pavements in the city. While possibly some occur, none was seen in the dozen or more streets examined by the writer, except a small crack across the pavements at the Victoria Market, said to be due to the shock.

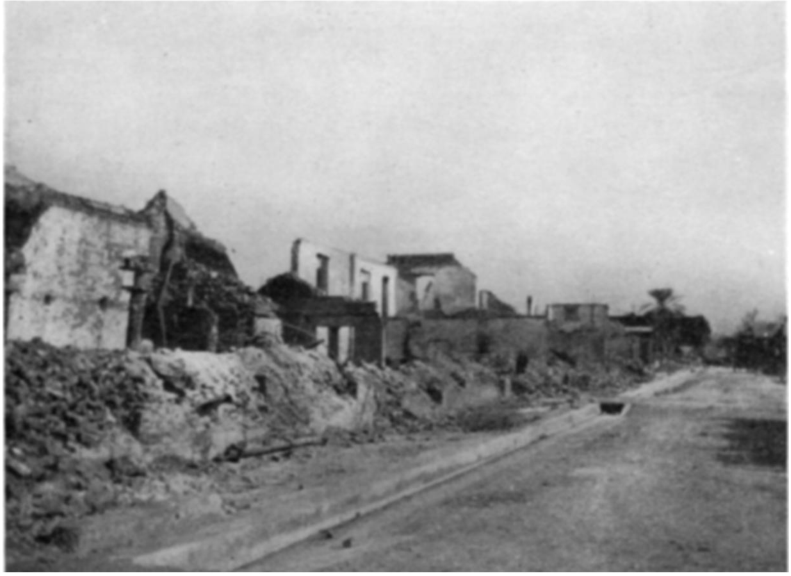

FIG. 10.—General view of ruins in fire district, Kingston, showing absence of disturbance in curbing. (Photo by Fuller.)

Reservoirs and water mains.—The reservoirs and water mains were somewhat disturbed, but not greatly so. The reservoir near Constant Springs was somewhat cracked, and the aqueduct at Hope Culvert broken and a part of the water supply cut off. The mains were rarely appreciably damaged.[1]

Railroad tracks and fixtures.—The steam-railway tracks were practically unaffected, and trains could be run with little difficulty almost immediately after the shock. On the Atlas Wharf, however, the tracks were warped slightly and had to be relaid. In the city a few trolley poles appear to have been titled by the shock, although the greater part were bent by falling débris. In the country few trolley or telegraph poles were affected, generally remaining upright even where near the sea. The sway of the poles seems to have been considerable, nevertheless, many of the wires being snapped, especially in the district east of the city.

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[1] The failure to get water during the fire was due largely to the burial of the hydrants by débris and injury to the engines by falling walls.

Rockfort District

Rockfort is the name applied to the old fort at the government quarries on the coast some three miles east of Kingston. A number of artificial structures were disturbed in this region, principally between the fort and the small stream entering the harbor beyond the old Naval Pier half a mile west of the quarry. At the mouth of the stream mentioned the cement culvert was much damaged, a part being buckled up and faulted (Fig. 11) while other parts were precipitated into the stream. At the same point the gutter was faulted downward several inches along the edge of the sidewalk. It is interesting to note in Fig. 11 that the wooden house, although near the region of greatest disturbance, is little affected.

Along the water front near here the sewer, a large iron pipe, was broken by the shocks, presumably by a buckling in the deposits.

Port Royal

Owing to the failure to get a permit to visit the fort the observations were mainly made from the water. The wooden tower at the southwest terminus is tilted 4 or 5 degrees from the perpendicular. One of the wharves on the harbor side appears to have been tilted toward the land at a considerable angle, the outer end being several feet higher than the inner. A railroad track was arched for a distance of twenty-five yards, the center being four feet above the ends. The sea wall was disturbed and tilted. Many buildings were severely wrenched and partially wrecked, the fact that the damage was not greater being due to the fact that they were of the frame type. One building was noted broken in two where the middle had sagged owing to a depression formed beneath it while the two ends remained elevated.

ATTENDANT FEATURES OF THE EARTHQUAKE

Tidal wave.—Kingston has an inclosed harbor one to two miles in width and five or six miles long, protected from the open sea, except at its mouth at the western end, by the long sand-spit or Palisadoes upon which Port Royal is located. Even the entrance is partially protected by reefs rising nearly or quite to sea level. It is to this fact that Kingston owed its immunity from tidal waves, except those generated within its harbor. These were relatively small, although large and powerful enough to throw one vessel up into the mud alongside the dock, while another, the Royal Mail Steamer "Arno," barely escaped wrecking by being thrown against the wharf.

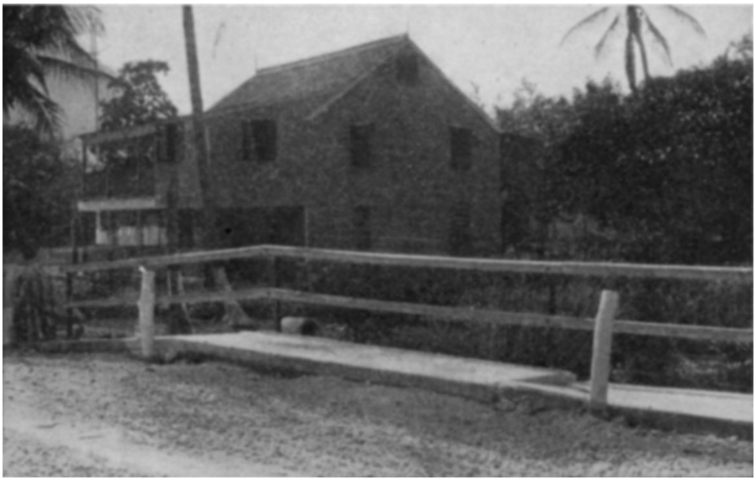

FIG. 11.—Sidewalk arched and faulted by lateral movement of the walls of a culvert toward the stream. Also illustrates the slight damage to wooden structures. (Photo by F. G. Clapp.)

Considerable waves were reported at sea, and one sufficient to move small buildings situated near the beach came ashore at Port Antonio on the northeast side of the island. Judging from the fact that the damage is no greater than it is at Port Royal, it is evident that the waves reaching shore at this point were of no great size. A large wave would have washed over the entire point, sweeping everything before it.

PROBABILITY OF FUTURE EARTHQUAKES

The earthquake of 1692 was much more destructive than the one of the present year. It was followed by a long period of relative quiescence, but with sufficient minor shocks to show that the readjustment was not complete until another great slip resulted in the shock of Jamaica, which, together with the subsequent tremblings, show the same is still true of the present time. A temporary local readjustment has, however, probably been reached, but although another severe earthquake may not occur in the near future, destructive shocks will almost certainly occur at some time in the future.

CAUSE

The writer believes the earthquake of January 14 to be due to a displacement along an east-west fracture probably not over three miles in depth at a point three or four miles south of the city, the greatest movement being at a point about four to five miles southeast of the city of Kingston. The disturbance is regarded as probably resulting either from isostatic readjustments or to fracture under the accumulated stresses due to processes of folding or uplift. The reasons are as follows:

1. The direction of movement along the south coast in the vicinity of Kingston varied from southeast-northwest to southwest-northeast, apparently indicating a long line of disturbance rather than a localized center, the position of the fracture being to the south and hence beneath the sea. Movement along such a fault explains the variation of direction of propagation of the vibrations near Kingston, and the tortional movement so characteristic of the later vibrations.

2. The area of greatest disturbance extended from the eastern part of Kingston to Bull Bay, some miles beyond the base of the Palisadoes, as shown by the more severe action on buildings, the greater frequency of fissures, the more profound disturbances in the rocks (as evidenced by the breaking out of springs), by the more frequent prevalence of faulting, fissures, craterlets, and warping in the Palisadoes, and especially by the profound disturbances of the sea bottom leading to the breaking of the cable at a point three and one-half miles southeast of the mouth of Hope River and the base of the Palisadoes.

3. The sharpness and intensity of the vibrations seem to be such as would characterize shocks arising from rock fractures rather than from disturbances due to the slipping of unconsolidated deposits on the inclined sea bottom as suggested by Dr. J. W. Spencer.[1] The shock was distinctly felt by the seismographs at the Weather Bureau at Washington, D. C., the amplitude of movement being about one-fiftieth of an inch, which it is believed would hardly have been the case if due to a landslide in superficial deposits.

4. The elevation of the east end of Jamaica, near which the faulting occurred, is about 7,400 feet, while the sea to the south is approximately 18,000 feet, making a total difference in level of over 25,000 feet. It can easily be conceived that isostatic readjustments, such as would tend to take place wherever such differences of level exist, at closely adjacent points, might have given rise to the fracture. It may be noted in this connection that each of the heavy earthquakes occurring in the western hemisphere in the last year—San Francisco, Valparaiso, Jamaica, and Mexico—all took place in regions of similar sharp differences in elevation. On the other hand, all are in regions characterized by more or less recent distortion, as brought out by the elevated beaches, warped and faulted beds, etc., and folding must be regarded as a possible source of the stresses giving rise to the fractures.

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[1] J. W. Spencer, *Science*, N. S., Vol. 25, 1907, pp. 966, 967.